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MINOR STUDIES FROM THE PSYCHOLOGICAL LABORATORY OF CORNELL UNIVERSITY

Communicated by E. B. TITCHENER and H. P. WELD

XX. ON THE LOCALIZATION OF PURE WARMTH SENSATIONS

By F. L. DIMMICK

In the experiments which this article reports we have studied the localization of points of warmth upon the cutaneous surface. The problem had already been attacked by Rauber¹ and by Ponzo,² but the results were not so definite as those obtained by Henri³ and others in investigations of the localization of pressure. Rauber employed as stimulus the radiant heat derived from a heated metal object inserted in the holes of a small piece of wood laid upon the skin; his results, which will be noted later, were too meager to allow us to judge of the success of the method; but it would appear *a priori* that the pressure aroused by the wood must have served as a distraction. Ponzo used as stimulus a small drop of warm water, which fell from a pipette through which had been drawn a fine cotton thread knotted at the lower end. Although this stimulus admittedly aroused pressure as well as warmth, the experiments were continued in the belief that the observers were able, by direction of attention, to abstract from the pressure sensation. But there is no certainty that this was the case; and it therefore seemed advisable to repeat the experiments with a stimulus that should completely avoid the arousal of pressure.

Method

We first tried, in a long series of preliminary experiments, the method advocated by Toulouse,⁴ and later employed by Kiesow and Ponzo⁵ and by Piéron⁶ in reaction experiments; but we found it

¹ A. Rauber. Ueber den Wärmeortssinn, *Centralbl. f. d. med. Wiss.*, 1869, no. 24, 372. We have not seen this article. Its method and conclusions are reported by A. Goldscheider, *Ges. Abhand.*, i, 179; T. Thunberg, in Nagel's *Handbuch der Physiol. des Menschen*, iii, 1905, 727; and E. Hering, in Hermann's *Handbuch der Physiol.*, iii, 2, 1880, 438.

² M. Ponzo, Studio della localizzazione delle sensazioni termiche di caldo e di freddo, *Riv. di Psic.*, ix, 1913, 393.

³ V. Henri, *Ueber die Raumwahrnehmungen des Tastsinnes*, 1898, 90-141.

⁴ E. Toulouse, N. Vaschide, et H. Piéron, *Technique de psychologie expérimentale*, 2d ed., i, 1911, 38.

⁵ F. Kiesow u. M. Ponzo, Beobachtungen über die Reaktionszeiten der Temperaturempfindungen, *Arch. f. d. ges. Psych.*, xvi, 1910, 376.

⁶ H. Piéron, Recherches sur les lois de variation des temps de latence sensorielle en fonction des intensités excitatrices, *Année psychologique*, xx, 1890, 34.

impracticable. Our observers, who had had extended practice in the analysis of cutaneous sensations, reported pressure in a large number of cases.⁷ We, therefore, abandoned the method and turned to radiant heat. This means of stimulation which, as we have seen, was employed by Rauber, appears also to have been used by Tanzi in reaction experiments; he describes his stimulus as the "irradiation from the tip of a flame."⁸ We resorted to an electrically-heated loop of platinum wire, which was enclosed in a tube in order to lessen the lateral radiation. The apparatus was made by running a piece of no. 20 copper wire through a glass tube 2 mm. in diameter, and another piece along the outside, and then connecting the ends by means of a loop of no. 24 platinum wire 1 cm. in length. This device was enclosed in a second glass tube, 4 mm. in diameter, in such a way that the loop came within 1 mm. of the end of the larger tube. The regular alternating current of the university lighting system was used in shunt with a Nichols' frame. An intensity of 8 to 10 volts was sufficient to bring the loop to a red glow in 1 to 2 sec.

A plaster cast was made of the arm of each observer.⁹ The observer, seated at a table divided by a screen, placed his right arm, volar side up, in the cast which lay to the right of the screen. An area 18 by 8 cm. was marked off into 2 mm. squares by means of a rubber stamp. Tattoo marks were made on the median line, to insure the setting of the stamp in the same place at every trial. In preliminary experiments, a number of warm spots were found by

⁷ These experiments were performed during the years 1912-13 by Mr. F. S. Kleinman under the direction of Dr. E. G. Boring. Many different sizes of pipettes were employed, but it was found impossible to obtain drops of water so small that they were not felt as pressure, even when the height of fall was not more than 2 mm. Later, the drop was applied by bringing it into contact with the skin, to which it adhered when the pipette was carefully removed. Still later, a tuft of cotton wool was substituted for the pipette. In this case, the drop was taken from boiling water and applied as quickly as possible. Again, however, about two-thirds of the applications aroused pressure as well as warmth. A fourth modification was tried: the tuft of wool and boiling water were employed as before, but now, in addition, a thin rubber membrane was stretched over the horizontal forearm; the pressure of the membrane was kept constant by hanging three weights (in all, 2 kg.) from the two edges of the membrane below the arm. The membrane was so thin that warmth was readily felt through it, and at the same time the skin was rendered less sensitive to pressure, either by adaptation or by a heightening of the limen. Even by this method, however, pressure was not entirely eliminated; it frequently happened that in a given sitting only a few pure warmths were obtained. Mr. Kleinman also attempted a modification of Rauber's method of obtaining radiant heat; the whole arm, except the region above a warm spot, was covered with a celluloid shield, and a very hot brass cylinder was brought close to the opening in the shield. The radiation, however, was not sufficient under these conditions to arouse warmth with any great regularity.

⁸ E. Tanzi, *Revista sperimentale di freniatria e di medicina legale*, xvi, 1890, 396.

⁹ We thought, at first, that casts would be necessary for the identification of the points in successive trials. The use of the rubber stamp made them unnecessary; but they were still a great convenience.

means of a von Frey warm-point. Those spots which gave a warmth of good intensity, and which were well removed from other warm spots, were chosen for the experiments. The area under experimentation was shaved, to prevent the arousal of pressure by touch of a hair.

The observer was required to indicate the point of stimulation on a life-sized photograph of the arm with the stamped area marked upon it. At no time during a series was he allowed to look at his arm.

The procedure was as follows. The observer was seated comfortably with his arm in the cast, and with his eyes either closed or directed on the photograph, as he preferred. The experimenter held the end of the stimulator, within two mm. of the skin, above the spot to be stimulated; gave the Ready signal; and closed the circuit. As soon as the observer felt a distinct warmth (in one to five seconds), he said 'There,' and the experimenter immediately broke the circuit. This was done in order that the stimulation might not become too intense. The observer now localized on the photograph the spot on his arm that had been stimulated. The actual process of localization differed with different observers, and will be described later.

Three observers took part in the experiments: Dr. E. G. Boring (*B*), instructor in psychology; Mr. G. J. Rich (*R*), an undergraduate in the department; and *D*, the experimenter. *B* and *R* observed in the systematic experimentation; after the regular work was completed, *R* served as experimenter with *D* as observer. This additional work was rough, and is taken into account only generally. Its main purpose was to give *D* an insight into the problem of localization from the observer's standpoint.

For the work with *B* and *R*, fifteen points upon or near the marked area were used, and ten series were worked through, making in all one hundred and fifty stimulations for each observer. With *D* only ten points were used, and only five series were taken. All of the fifteen points were stimulated in haphazard order in every series, and a rest of at least five minutes was given between series.

Besides the series with the warm stimulus, five series with a pressure stimulus were taken. A von Frey hair-aesthesiometer was employed as stimulator. The results from these series were employed for purposes of comparison and control.

Results

Method of Localization.—Henri, in his investigation of pressure localization, finds that observers fall into two groups. The one group localizes only after deliberation and verification of the point, the other localizes the point almost immediately. Henri further distinguishes the members of the two groups as those with good and those with poor visual imagery. The first difference appeared, by chance, in our two observers; the second distinction, however, did not appear. Both *B* and *R* reported in the early experiments that localization seemed to be visual; but later they declared that it was largely kinaesthetic. The difficulties and methods of localization are noted in the introspective reports. *B* remarked, at the beginning of the experiments: "Crosswise localization was almost immediate and always first. Refer to one side or the other before looking at the photograph. Considerable difficulty as to place up and down; also transversely as to how near the edge the localization occurs, particularly in the region

C-R [see Fig. 1]. Photograph not real like the arm; lower and upper portions more real. In central part the localization is hard."

R's reports at first are not full; yet they give some indication of his difficulties. "I have a feeling of uncertainty. There are no objective criteria. Localization seems to depend upon the part of the arm attended to."

At the end of the second series *B* reported: "I get a visual image of the place on the arm, and place the point in relation first to the wrist and then to the elbow." Later on, however, he decided that the "localization was rather kinaesthetic than visual."

The same thing was noted in the introspection of *R*. "Visual image of arm and place where warmth is felt. Not very definite. Use after-images." Later he reported that he had a kinaesthetic 'feel' in the left arm when he had moved the pointer to the right place on the photograph.

D, in the rough work performed by him, localized visually. He found no kinaesthesia; but this negative result may be due to the fact that his experience was only one-third as great as that of the others. He confirmed the reports of *B* and *R* as to the uncertainty and difficulty of localization.

Qualitative Observations.—Several observations of a qualitative kind appear in the reports, particularly in those of *B*. It is to be remembered that at no time during the experiment was anything allowed to come into contact with the surface of the skin under experimentation. Yet both observers often reported 'pressure.' They were asked to attempt an analysis, in the hope that some explanation might be found. *R* found nothing; but *B*, who is unusually practised in cutaneous work, reported for one stimulation as follows. "Seemed to get a pressure. It has a dull, blurry, diffuse, smooth, almost soft, mushy character; and I should say that these terms were not merely attempts to describe the indescribable, but mean actual pressure." Again he reported: "Many of the warmths seem pressury. Once I got a sort of stingy, puckery feel, which (it occurred to me) might be what makes the warmth seem pressury. There seems to be a stage when there is a very faint sensation in which I am certain neither of the location nor of the quality. Later I come to place it and then to judge its quality. On the contrary, I did get one or two warmths definite as to quality, but very indefinite as to localization until they became stronger."

It is possible that the radiant heat causes the skin to contract, and thus produces a direct stimulation of the organs of pressure. Since, however, the results do not show that the observer is more accurate in his localizations when pressure is reported, we are forced to leave the question open.

Results of Localization.—Three general statements may be made: (1) there are very noticeable tendencies in direction of localization; (2) certain areas are preferred for localization; and (3) the error is very large.

(1) Let us first consider the tendencies of direction with regard to imaginary xy axes; the y axis running up and down through the centre of the mapped area, and the x axis crossing at right angles in the centre. If we examine the results of *B*, we find that the localization of points at some distance above the x axis tends toward *P* and the y axis; while that of points below the x axis tends toward *C* and (with one exception) toward the y axis. But points near the

x axis, on both sides, may be localized *either up or down*. It follows that our ' x axis' should be not a line but a band. Moreover, since there are two points, the one just on the C side and the other on the R end of the x axis, both of which have a tendency toward P , the band should also be somewhat turned (see Fig. 1). We may say in general, then, that the tendency is *in from the edges* of the mapped area.

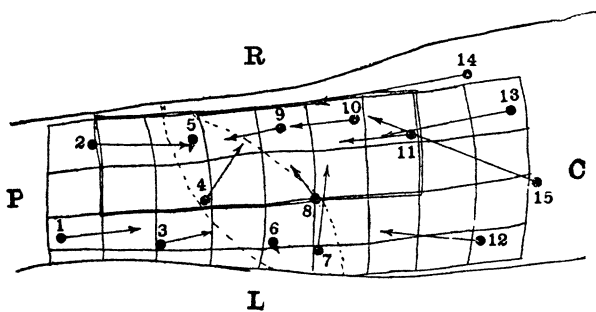


FIG. 1. Obs. B

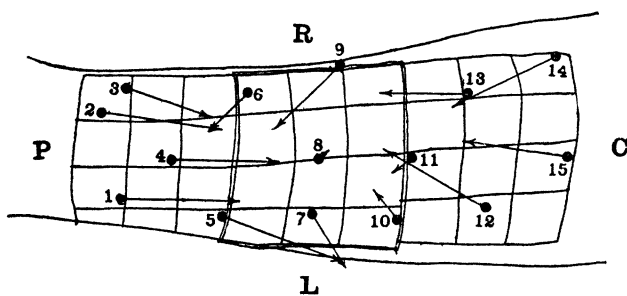


FIG. 2. Obs. R

The arrows in the diagrams indicate for any given point the average displacement of the localization both in amount and in direction. The values were found by computing the average component in the left-right direction and in the central-peripheral direction (adding algebraically for localizations made on different sides of the point), and constructing the hypotenuse upon these two components. The arrow-tip thus lies at the centre of gravity of all the localizations made. The length of the line does not represent the average error (Table III), which is computed independently of the direction of reference, but the average displacement in the direction indicated.

There is a striking resemblance between the results of B and those of R . If we turn to R 's results, we see that the y axis coincides with that of B . The x axis is even more regular, including an area 6 cm. wide, across the middle of the mapped area, at right angles to the x axis (see Fig. 2). Here, again, the tendency is *in from the edges*.

An attempt has been made in the following Tables to give a quantitative presentation of the tendencies. Table I shows the average or resultant tendencies in the *PC* and *RL* directions (see Fig.). Both the direction of error and its amount in that direction are taken into account. If, for instance, the given localization be considered as a force, then the *P* or *C* value represents the component force in the longitudinal direction, and the *R* or *L* value the component force in the lateral direction. The resultant from these two would give the amount and direction of the point's movement.

TABLE I

THE AVERAGE OR RESULTANT TENDENCIES (IN MM.) IN THE LONGITUDINAL AND LATERAL DIRECTIONS. DOWN (*P*), UP (*C*), RIGHT (*R*), LEFT (*L*)

No. of point	Observer B				Observer R			
	Directions				Directions			
	P	C	R	L	P	C	R	L
1 .....	....	30.5	1.9	....	....	48.2	....	4.2
2 .....	....	38.9	....	2.9	....	46.7	....	8.7
3 .....	....	20.2	2.5	....	....	33.6	....	13.3
4 .....	....	17.2	20.7	....	....	43.2	....	3.5
5	0.9	....	....	3.1	....	48.8	....	13.0
6 .....	....	0.7	....	4.7	17.0	....	....	14.7
7 .....	....	6.2	33.6	....	....	12.2	....	22.4
8	8.7	....	13.9	....	....	3.5	2.4	....
9	28.2	....	....	2.3	28.8	....	....	28.3
10	25.8	....	....	0.4	8.5	....	11.9	....
11	28.5	....	0.7	....	8.4	....	....	5.5
12	43.6	....	6.4	....	39.2	....	24.6	....
13	52.9	....	....	3.4	35.0	....	1.4	....
14	61.4	....	....	5.4	43.9	....	....	16.7
15	66.0	....	32.7	....	40.8	....	7.8	....

In numbering the points, we begin at the *P* end of the area and go toward the *C* end. Consequently, the values in the *P* column of Table I begin at 0 and increase, while those in the *C* column begin high and decrease, as we go from *P* to the *C* end of the area. Those in the middle area have very small tendency-values as compared with the others.

The same thing for the lateral direction is shown in the *R* and *L* values. It does not appear so definitely, however, because the points are first on the one side and then on the other of the median line.

Since in Table I one large error in one direction may have more influence in the average than two or three smaller errors in the other direction, some of the averages do not fully evaluate the tendencies. We therefore present another Table, which exhibits the tendencies without regard to the amount of error. Table II indicates the tendencies of direction according to the actual number of localizations in every one of the four directions for every point. When either of the sums $P+C$ or $R+L$ is less than 10, the remaining localizations

were in a line with the point stimulated, and at right angles to the absolute direction in question; thus, if $P+C=9$, one point was localized on the line passing through the point and perpendicular to the median line. Table II, then, shows the same results as Table I, but in a different way. It also shows that the change in tendencies, as we go from the one end to the other, occurs not abruptly but gradually.

(2) The next point to be noted is the favoring of certain areas. These are outlined doubly in the Figg. For *B* the area lies along the *R* side of the mapped area, and contains 66⅔% of all localizations.

TABLE II
THE TENDENCIES OF DIRECTION ACCORDING TO THE ACTUAL
NUMBER OF LOCALIZATIONS IN EACH ONE OF THE FOUR
DIRECTIONS FOR EVERY POINT

No. of point	Observer B				Observer R			
	Directions				Directions			
	P	C	R	L	P	C	R	L
1	0	10	5	5	0	10	2	8
2	1	9	2	7	0	10	2	5
3	2	8	6	3	1	8	1	6
4	4	5	10	0	0	9	2	3
5	4	5	1	7	2	8	6	0
6	5	5	5	6	3	7	2	8
7	5	5	9	1	3	7	10	0
8	6	4	9	1	6	4	7	3
9	8	1	2	6	6	2	0	10
10	8	1	5	3	7	3	9	1
11	8	1	3	6	6	4	4	6
12	9	1	7	3	7	3	7	2
13	9	1	5	3	8	2	3	3
14	10	0	2	6	10	0	2	7
15	10	0	9	1	10	0	5	5

An illustration may assist in making the table clear. Spot No. 9 (Obs. B) was localized 8 times below the point, once above the point, and once neither above nor below. The same spot was also localized twice to the right, 6 times to the left, and twice neither to the right nor to the left.

For *R* the area is coincident with *x*, *i. e.*, it is 6 cm. wide, and extends across the middle (up and down) of the mapped area. It contains 50% of all the localizations. *B* reported that he was "prejudiced by the stamped area, in that there was a tendency to localize well within it." This prejudice does not, however, account for the extreme favoring of a single area, a fact for which there is no explanation in the observers' reports.

(3) Finally, the error of localization is itself exceedingly large. Of the 300 localizations made by the two observers, only 4 were correct, *i. e.*, fell within the area of 4 mm. A larger number might have been expected to occur by chance. Only 20 localizations were made

with an error of less than 10 mm. The extremes were 146 mm. for *B*, and 132 mm. for *R*. Table III gives the average errors for each point, and their mean variation.

We have here a rough measure of the inability of the observers accurately to localize pure warmth. We find average errors ranging from 15 to 63 mm., and mean variations often more than half the value of the average error.

Pressure.—It was said above that five series were performed with a pressure stimulus for the sake of comparison with the main series. The results obtained with pressure were similar to those got by Henri under similar conditions and by the same method. The errors were comparatively small, the average error for *B* being about

TABLE III
AVERAGE ERROR (IN MM.) AND MEAN VARIATION FOR EACH POINT

No. of point	Observer B		Observer R	
	A.E.	M.V.	A.E.	M.V.
1	30.9	15.28	57.6	25.12
2	28.1	14.80	50.4	31.80
3	27.9	9.70	43.4	20.04
4	35.2	14.58	43.2	21.80
5	15.8	8.96	58.8	27.60
6	24.6	15.60	33.5	16.10
7	44.8	12.60	31.2	11.90
8	22.2	5.04	25.0	15.20
9	31.1	11.48	46.6	18.50
10	24.4	16.00	25.3	12.22
11	32.1	18.12	22.2	6.60
12	52.5	22.40	57.9	25.12
13	51.6	9.58	51.1	16.68
14	59.9	25.00	46.4	17.78
15	63.8	25.04	45.1	12.10

11 mm., and for *R* about 20 mm.,¹⁰ and the localizations were clustered around the point of stimulation instead of tending in a single direction as was the case with warmth. It seems, then, that the observer has far less ability to determine the position of a point on the skin when it is stimulated by warmth than when it is stimulated by pressure.

Previous Work.—A comparison of these results with those of previous investigators of the localization of warmth shows both agreement and disagreement. Rauber concluded that the 'warm circles' are larger than the corresponding 'touch circles.' In so far as this statement means that the error of localization of warmth is greater than that of the localization of pressure, we agree. Ponzo reached the same general conclusion, although his average errors and mean variations are much smaller than ours. Furthermore, Ponzo's results show

¹⁰ These average errors are larger than they should be, because only five series were taken, and a few large accidental errors raised the average.

errors of direction which group about the point of stimulation, while the results of our experiments show a tendency to localize certain points in certain areas. These differences are doubtless attributable to differences in method. Ponzo employed a stimulus that was not free from pressure, his observers localized by touching the arm, and the warm spots were localized but five times as against our ten.

XXI. FORM *vs.* INTENSITY AS A DETERMINANT OF ATTENTION

By L. G. MEADS

President Sanford once asked the senior editor of these studies if it might not be possible to compare form and intensity of stimulus, in some quantitative way, as regards their power to compel the attention. The present experiments give a first, rough-and-ready answer to this question in a single case. A light-form of varying intensity was compared with a 'formless' spot of light of fixed intensity, and that ratio of the objective intensities was determined at which the two stimuli were judged equally clear.

Apparatus.—The apparatus consisted of a projection lantern with tachistoscopic attachment; a black box with three openings, one to admit the light of the lantern, and two front circular openings (8 cm. in diameter, 18 cm. apart) covered with ground glass, through which the light passed to a large ground glass screen (150 by 105 cm.); and an episcotister placed between box and screen. The tachistoscope gave an exposure of a tenth of a second (110 ± 8 sigma). One-half of the screen was covered with a sheet of thick paper, in the centre of which was cut a square cross (9 by 9 cm.; width of arms, 4 cm.); the episcotister was placed always on the same side as the cross. A small electric bulb, set midway between the stimuli, served as fixation-point. The 'formless' spot was, of course, roughly circular; it had a bright central area of some 12 cm. in diameter, and a total diameter of some 17 cm., and was therefore considerably larger than the cross; it made an impression of vagueness and diffuseness, and the observers never named its form, but referred to it as the 'spot' or 'patch' of light.

The observations were made in the dark room and with dark adaptation. The observers sat at a distance of 3.75 m. from the screen.

Method.—The instructions were as follows: "At the signal Now! you will fixate the spot on the glass; a second and a half later, two spots of light will be shown. You are to report which of the two (if either) is the more clear." The observer was further instructed that observations would be made in series, in some of which the one and in others the other spot would at first be definitely the clearer.

In the descending series the light of the cross was cut down to 180° of the episcotister, while the formless spot was presented at full intensity; in the ascending series the light of the cross was cut down to 84° . Preliminary experiments had shown that at 180° the cross would always be the clearer, and at 84° would always be the less clear stimulus. The steps in both series were 12° .

Two observers made 40 series; ten ascending and ten descending with the cross on the right, and the same number with the cross on